Megacities and Their Impacts
From The Urban to the Global Scale

Jeff Gaffney

Global Change Education Program

GLOBAL CHANGE EDUCATION PROGRAM

ARGONNE NATIONAL LABORATORY
operated for
the U.S. Department of Energy
by The University of Chicago

Permanent Gases

Nitrogen	78.08%
Oxygen	20.95%
Argon	0.93%
Neon	0.0018%
Helium	0.0005%
Methane	0.0001%
Hydrogen	0.00005%
Xenon	0.000009%

Variable Gases

Water vapor	0-4%
Carbon dioxide	0.034%
Ozone	0.000004%
Carbon monoxide	0.00002%
Sulfur dioxide	0.000001%
Nitrogen dioxide	0.000001%
Dust, soot, etc.	0.00001%

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MOSES MAIMONIDES – 1135-1204

“Comparing the air of cities to the air of deserts and arid lands is like comparing waters that are befouled and turbid to waters that are fine and pure. In the city, because of the height of its buildings, the narrowness of its streets, and all that pours forth from its inhabitants and their superfluities… the air becomes stagnant, turbid, thick, misty, and foggy… If there is no choice in this matter, for we have grown up in the cities and have become accustomed to them, you should… select from the cities one of open horizons… endeavor at least to dwell at the outskirts of the city…

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John Evelyn, Esquire (1620-1706)

"…. This horrid Smoake which obscures our Church and makes our Palaces look old, which fouls our Cloth and corrupts the Waters, so as the very Rain, and refreshing Dews which fall in the several seasons, precipitate to impure vapour, which, with its black and tenacious quality, spots and contaminates whatever is exposed to it… it is evident to every one who looks on the yearly Bill of Mortality, that near half the children that are born in London die under two years of age.

Note: A child born in a Country Village had an even chance of living 40 years.

World's Top Ten Cities - Population

City	Pop. - 1991	Pop. - 2000
TOKYO, Japan	27,245,000	29,971,000
Mexico City, Mexico	20,899,000	27,872,000
São Paulo, Brazil	18,701,000	25,354,000
Seoul, South Korea	16,792,000	21,976,000
New York, USA	14,625,000	14,648,000
Osaka, Japan	13,872,000	14,287,000
Bombay, India	12,101,000	15,357,000
Calcutta, India	11,898,000	14,088,000
Rio de Janeiro, Brazil	11,688,000	14,169,000
Buenos Aires, Argentina	11,657,000	12,911,000

AEROSOLS..

OPTICAL PROPERTIES OF AEROSOLS

INFRARED – LONG WAVE RADIATING FORCING OF AQUEOUS AEROSOLS

VISIBLE – CARBONACEOUS SOOT

AGE DATING AND NATURAL RADIONUCLIDES

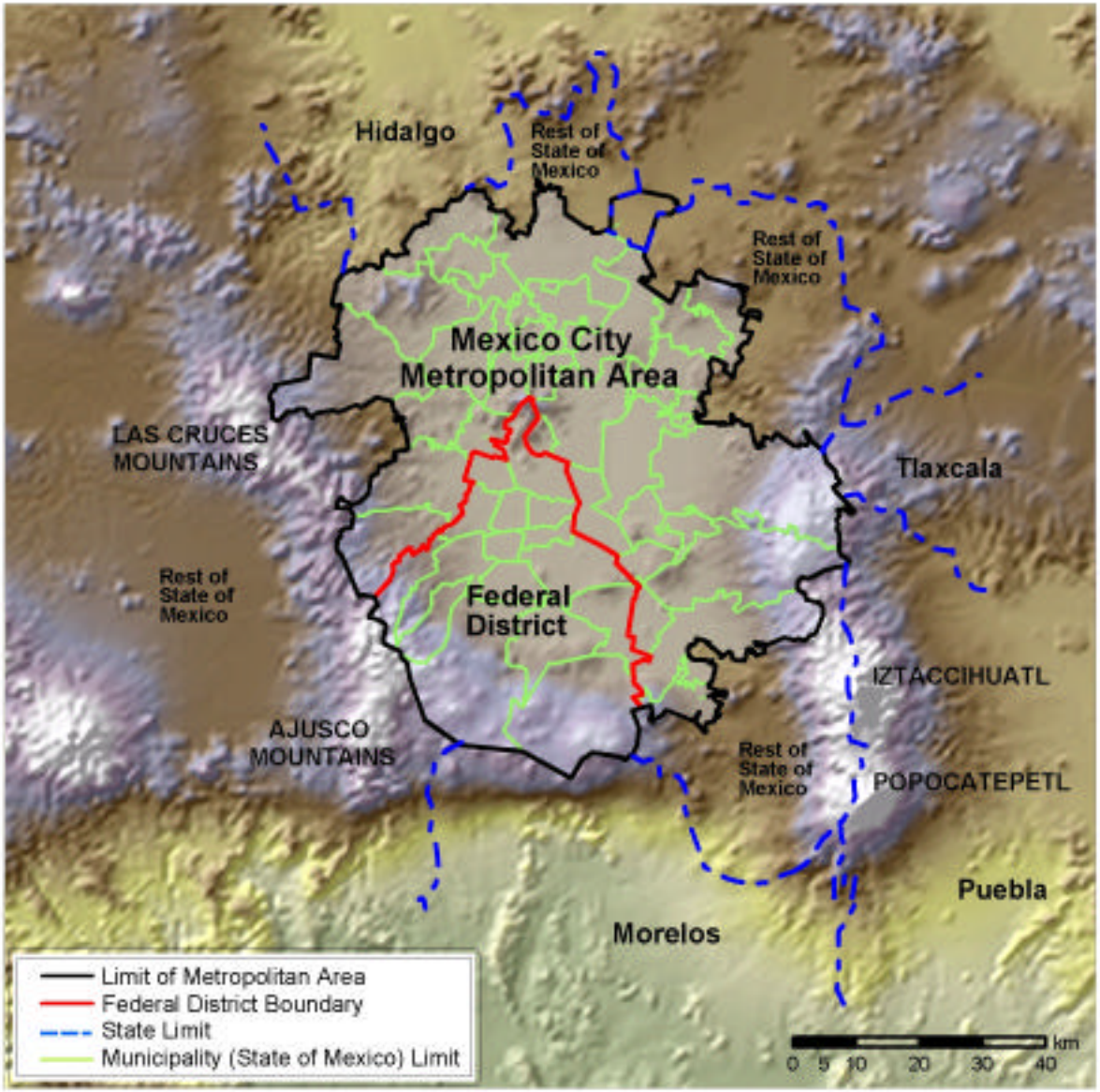
210Pb AND 7Be

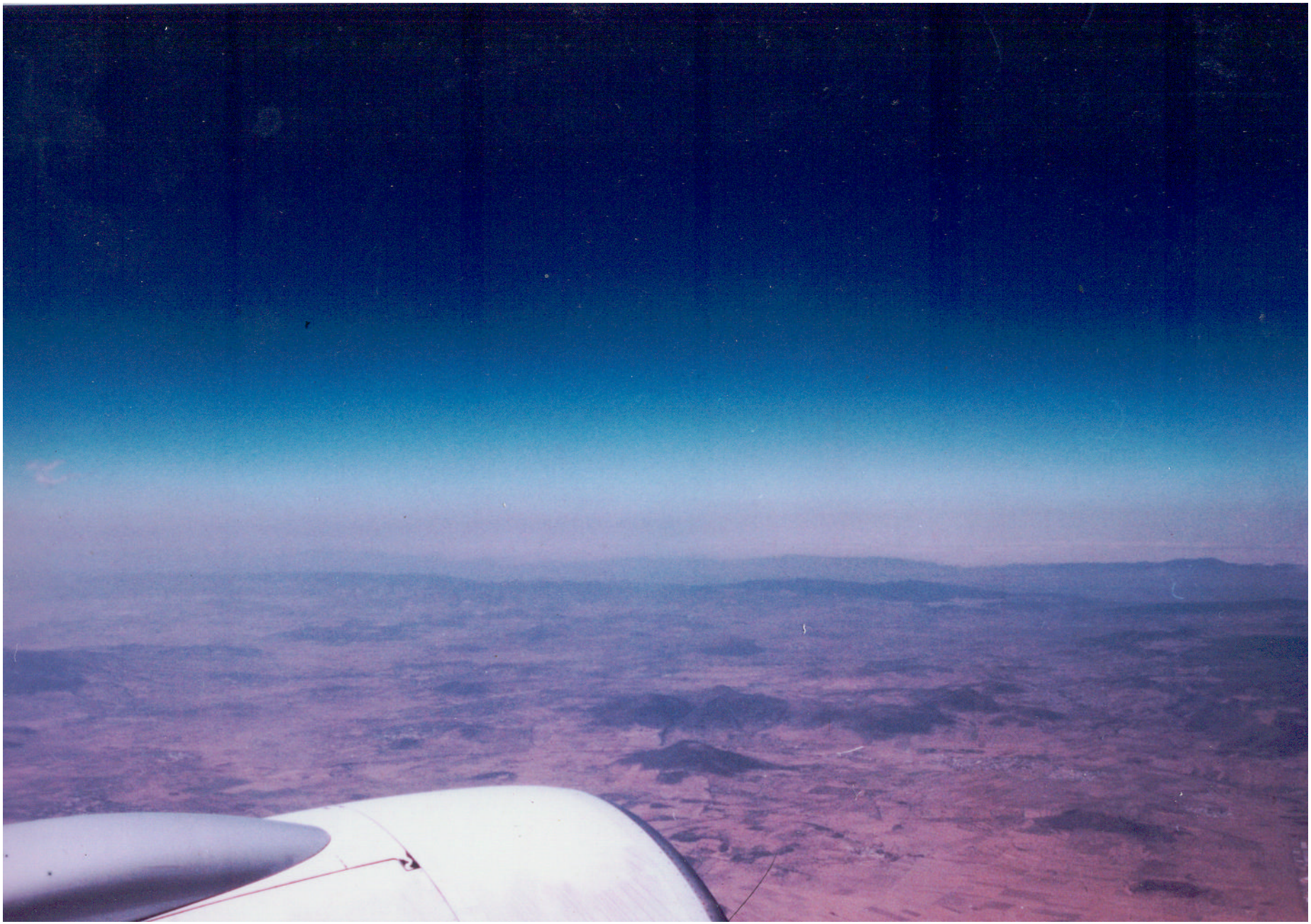
RADIATIVE EFFECTS – FIELD STUDIES

BLACK CARBON – AETHALOMETER – ABSORPTION

NEPHELOMETER- LIGHT SCATTERING

MEXICO CITY - Topographical Map of the MCMA





Estimated Mass of Emissions in Mexico City Plume

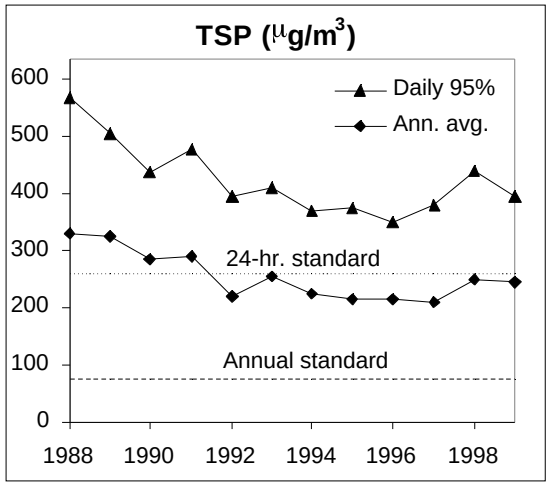
Pollutant	Concentration	Metric Tons per Day	Mega-Tons per Year
NMHC	1 ppmC	4500	1.6
CO	5 ppm	43,000	16
NO_2	50 ppb	710	0.26
Ozone	200 ppb	3000	1.1
PAN	20 ppb	750	0.27
PM-2.5	$50\mu g/m^3$	40,000	15

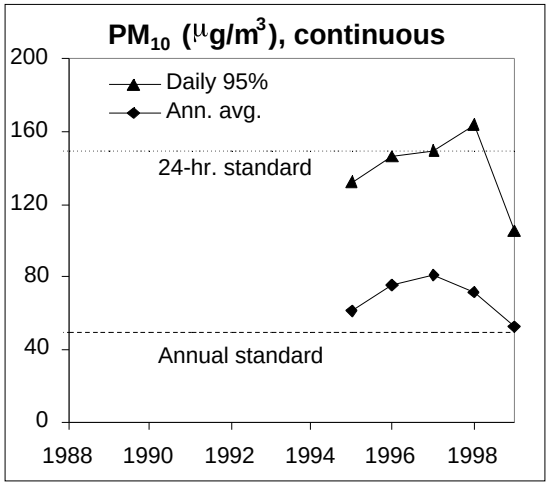
Assumptions: 770 mbar, 27 C, 2 km mixing layer, 5000 km^2 Metropolitan Area, no dry deposition, Air Mass is completely mixed and flushed out once a day.

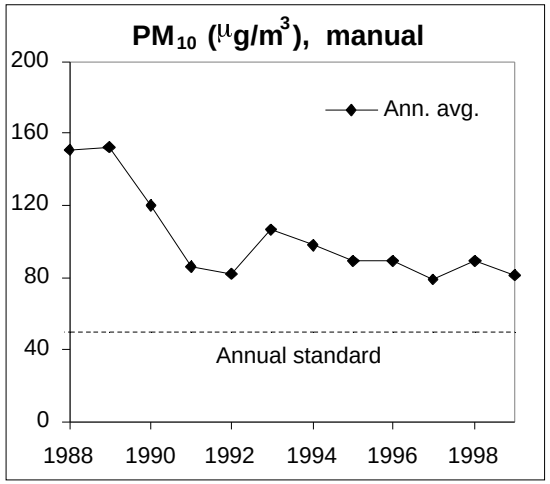
Comparison of selected statistics between the MCMA and the South Coast Air Basin

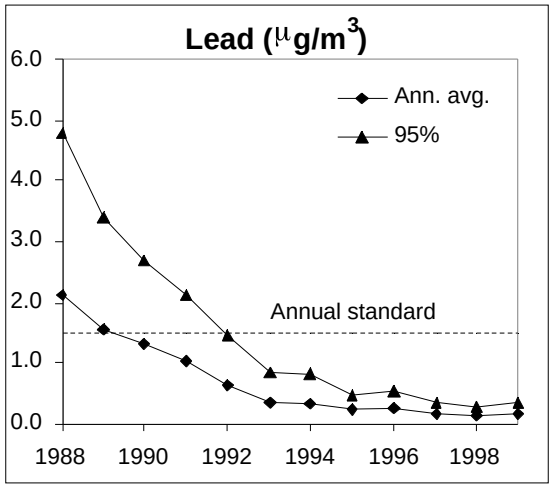
	South Coast Air Basin[a]	MCMA[b]
Population (2000)	15 million	18 million
Total area (km^2)	27,800	5,300
Urbanized area (km^2)	17,500	1,500
Population density (inhabitants/km^2)	840	12,000 (central area) 2,700 (periphery)
GDP per capita (2000) in US dollars	32,700	7,750
Energy consumption (petajoules)	4,100	720
Fuel consumption (gasoline) liters/day (1999)	76 million	18 million
Fuel consumption (diesel) liters/day (1999)	10 million	Total =5.3 million Automotive = 4.4 M
Vehicle fleet (1999)	9.3 million	3.2 million
Average Vehicle age (years)	~10	~10
Vehicle emission control technology (1998)		
Pre-control	1 %	50%
Early control	8%	22%
Tier 0	66%	28%
Tier 1	25%	~0
VKT (kilometers per day)	512 million	153 million
Peak ozone conc. (ppbV) in 1999	176	321
Peak PM_{10} conc. ($\mu g/m^3$) in 1999	139	202
NO_X emissions (tonnes/yr)	400,000 (2000) (80% vehicles)	206,000 (1998) (80% vehicles)
VOC emissions (tonnes/yr)	362,000 (2000) (40% vehicles)	475,000 (1998) (40% vehicles)

Trends in criteria pollutant concentrations for the MCMA showing the averages of data at five RAMA sites (TLA, XAL, MER, PED, and CES)









Mexico City 1997

Mexico City 7:50 am 2/21/97

LOTS OF AEROSOLS

>50 ug/m^3 PM-2.5

50% Organic and Soot

Table 1. Estimated Mass of Emissions in Mexico City Plume based upon the following assumptions: 770 mbar, 27 C, 2 km mixing layer, 5000 km^2 Metropolitan Area, no dry deposition, air mass is completely mixed and flushed out once a day (Gaffney, 1999).

Pollutant	Concentration	Metric Tons per Day	Mega- Tons per Year
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MEXICO CITY PLUME – FEBRUARY 1997

Ground-Based Measurements

Late March-April-Early May 2003

- **BLACK CARBON**
- **Nephelometer**
- Ammonia
- **PAN** – missing NOy
- **Holy Week** – Vehicle Traffic Reductions Anticipated

CENICA – Super site

April 2003 Intensive Field Measurement Campaign

Supersite at CENICA (Ixtapalapa)

- Fixed Site Aerosol Mass Spectrometer (Aerodyne)
- Tall flux tower (Washington State University)
- UV-VIS DOAS (University of Heidelberg/MIT)
- LIDAR (University of Berlin/MIT)
- Tethered balloon (CENICA)
- Vertical atmospheric radiosondes (IMP/MIT)

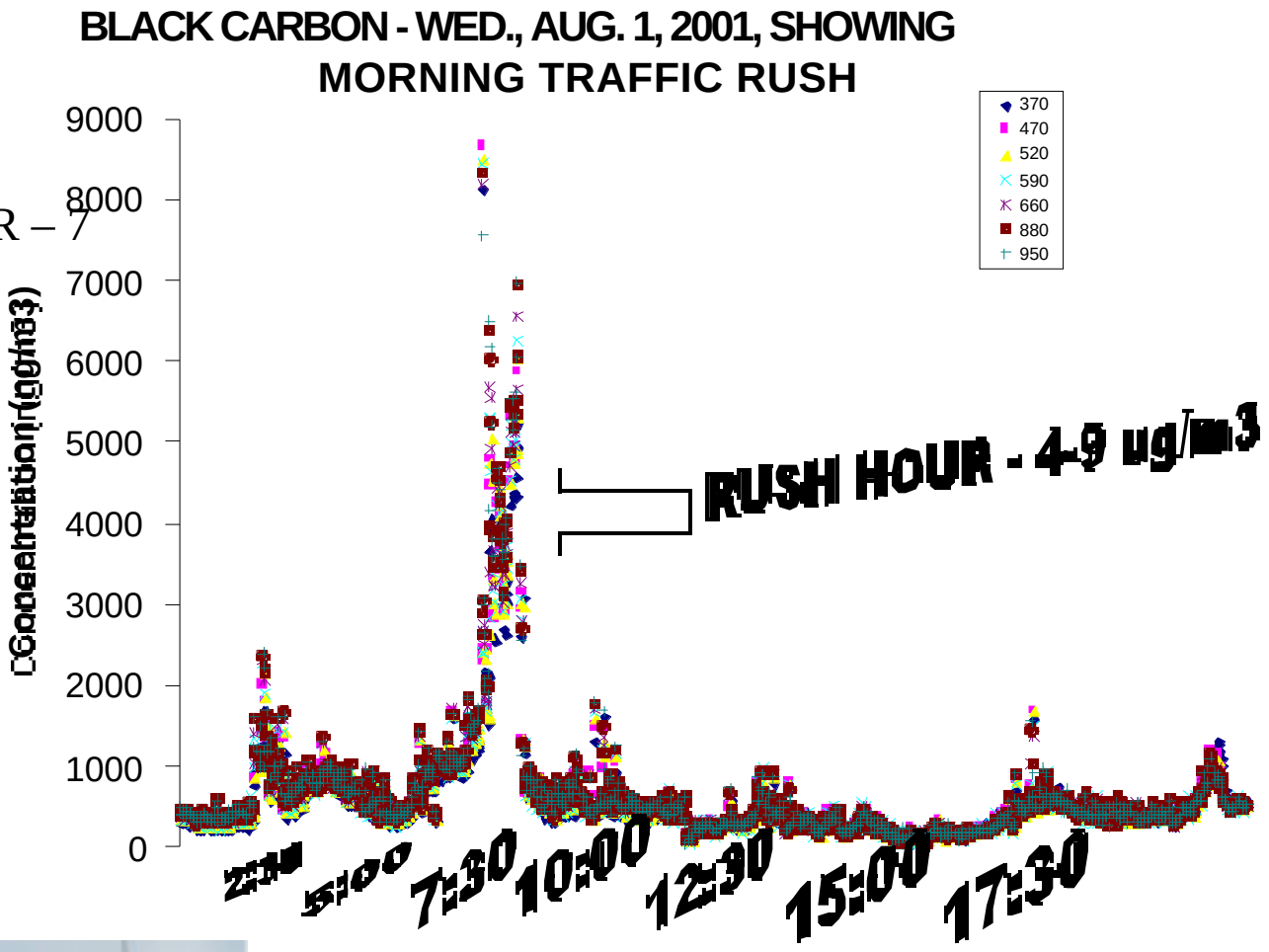
- Fast GC with Luminol detection method - PAN, NOx (ANL)
- Aethalometer - black carbon (ANL)
- Tunable-diode laser systems for NH_3 and CH_2O (ANL)
- VOC Canister sampling (ANL)
- Fast GC with OLEFIN Detector- isobutene (ANL)
- DOAS (Stutz, UCLA)
- Nitroarenes (Arey, Atkinson, UCRiverside)
- Organic Carbon/Elemental Carbon (LBNL)

AMMONIA – IMPORTANT IN FORMATION OF AEROSOLS

TUNABLE DIODE SYSTEM – NEAR-IR LINE

TELESCOPE/REFLECTOR SYSTEM – 244 M PATH

AETHALOMETER – 7 CHANNEL



Chicago, IL

April 2003 Intensive Field Measurement Campaign

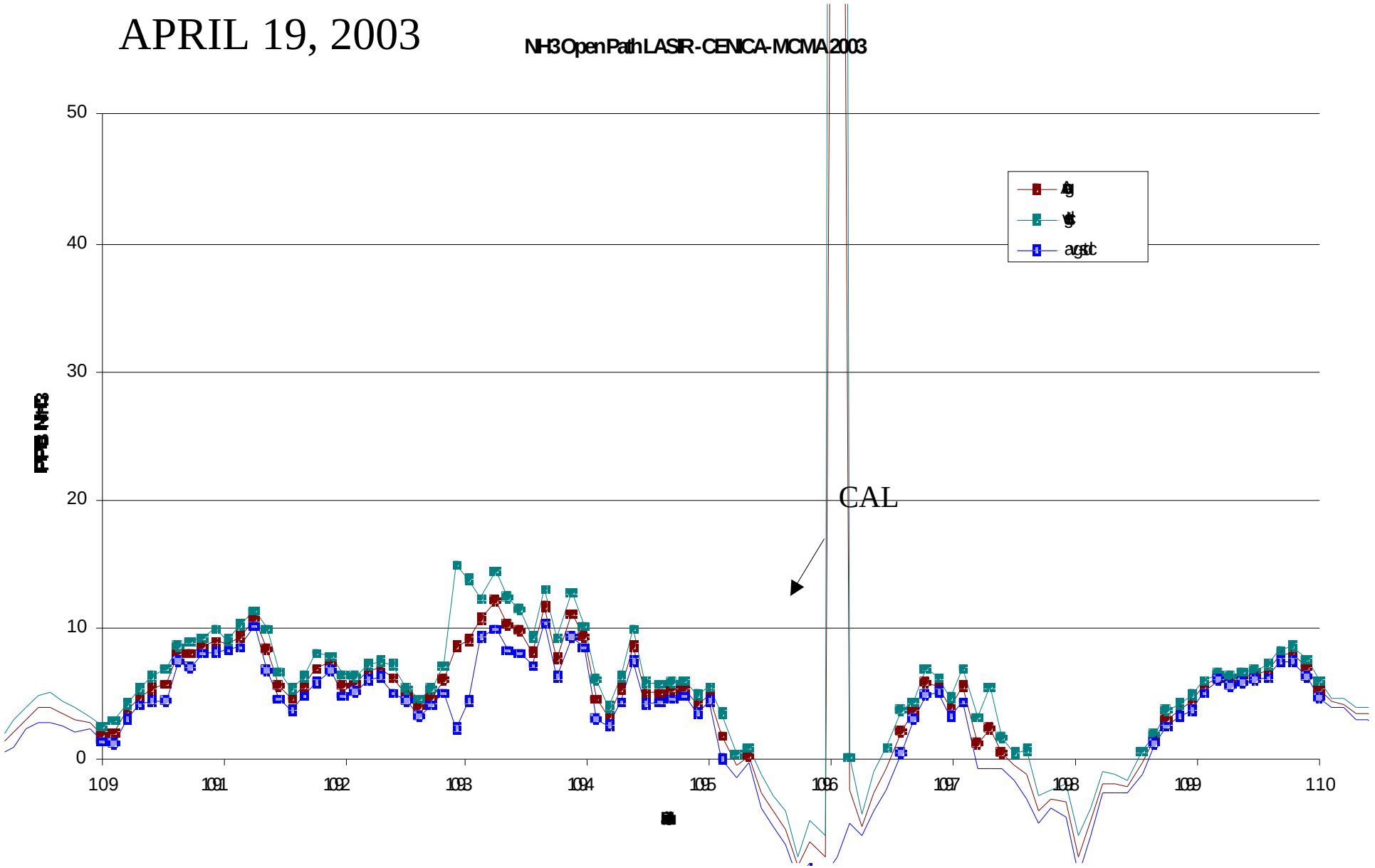
Mobile Laboratory Additions

NH_3/HNO_3 /HONO QC-TILDAS (ARI)
Chemiluminescent NOy instrument (MIT)
PTR-MS (MSU)
Realtime Canister/Cartridge Autosampler (WSU)
PAN/NO2 (ANL)

Other Complementary Measurements

Cartridges for Carbonyl compounds sampling (IMP)
MINIVOLS and MOUDI for PM10 and PM2.5 (IMP)
Sun photometer, CCN counter, nephelometer, MOUDI filter (UNAM)
(at selected mountain passes around the basin)

APRIL 19, 2003



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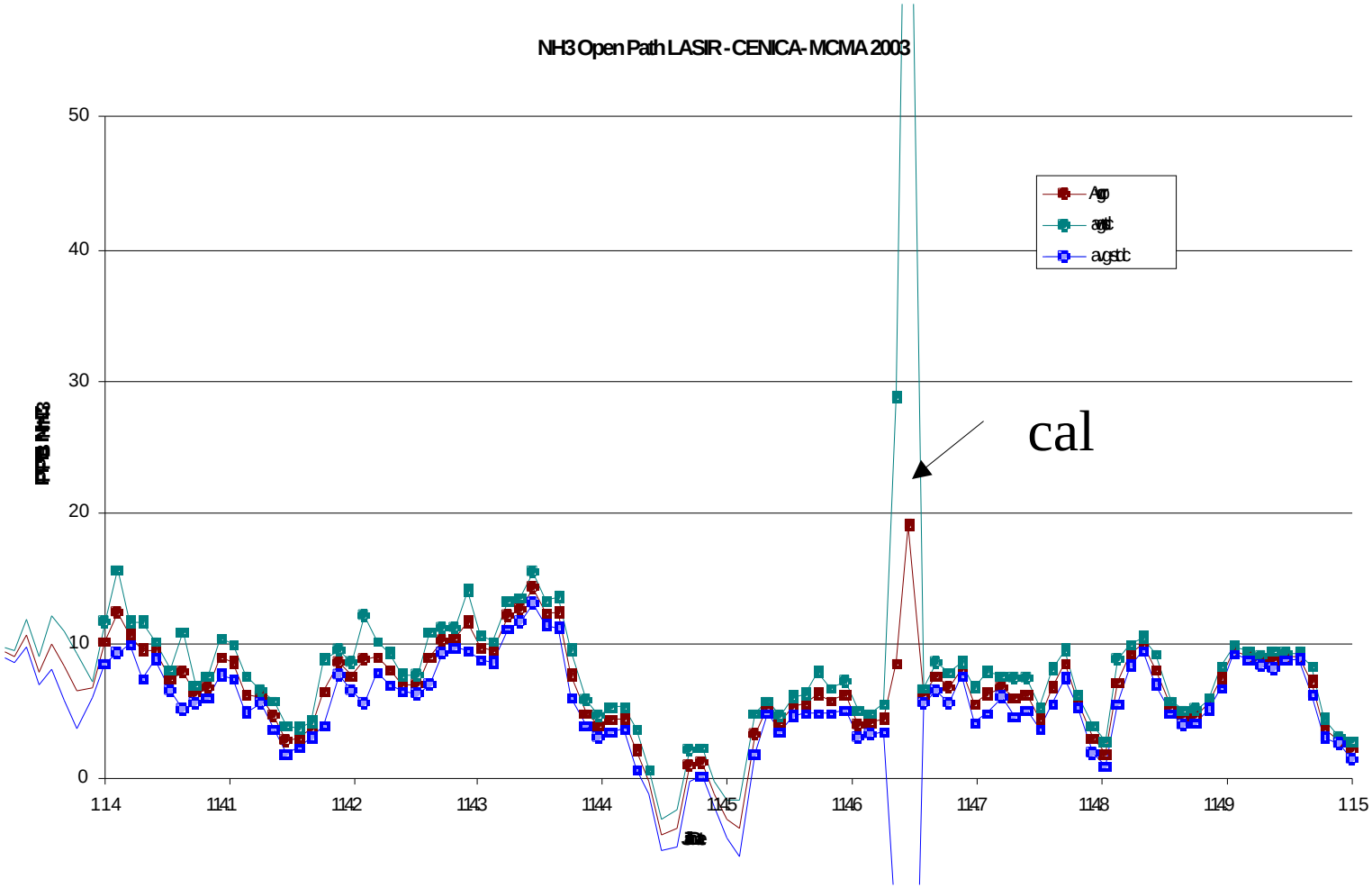

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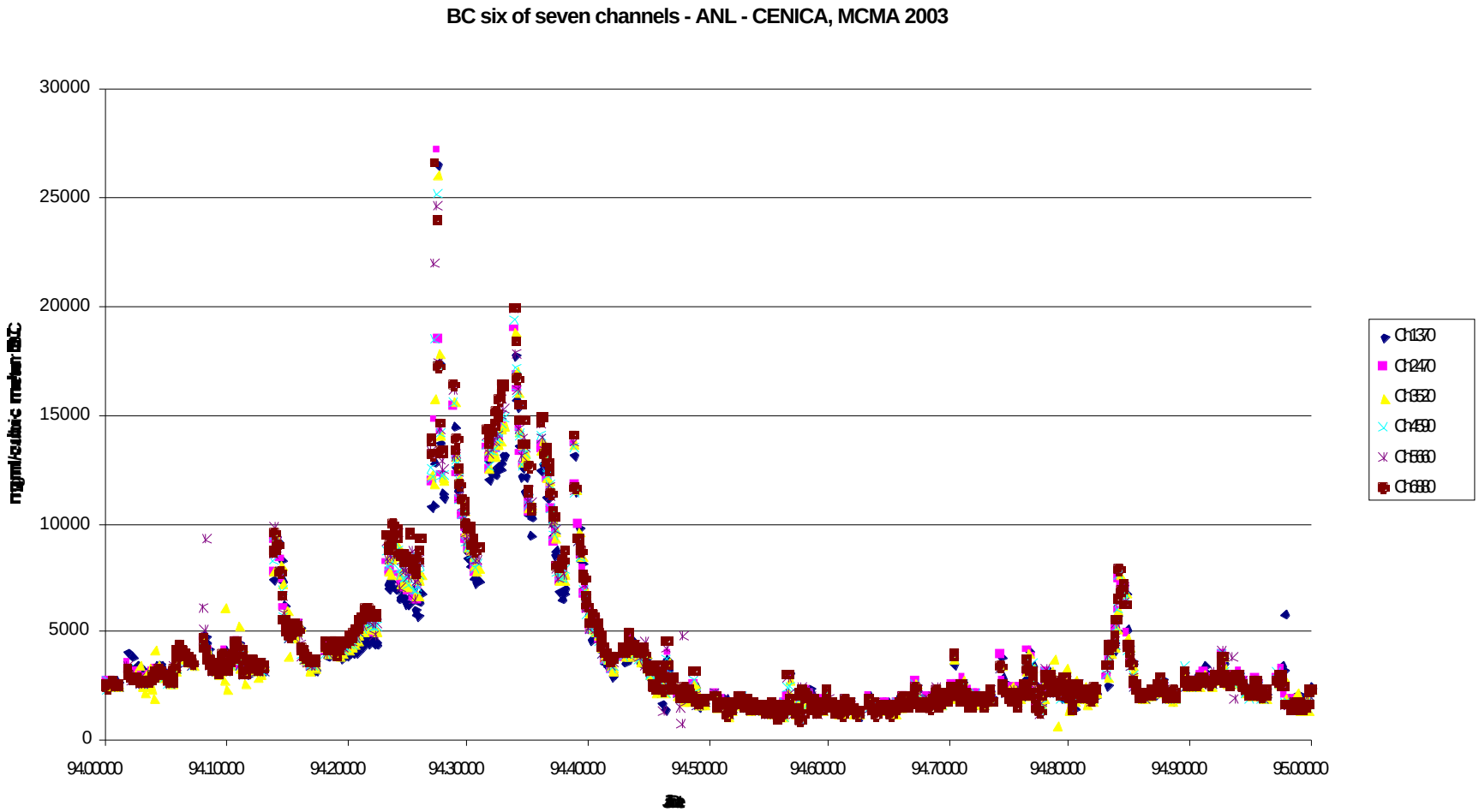
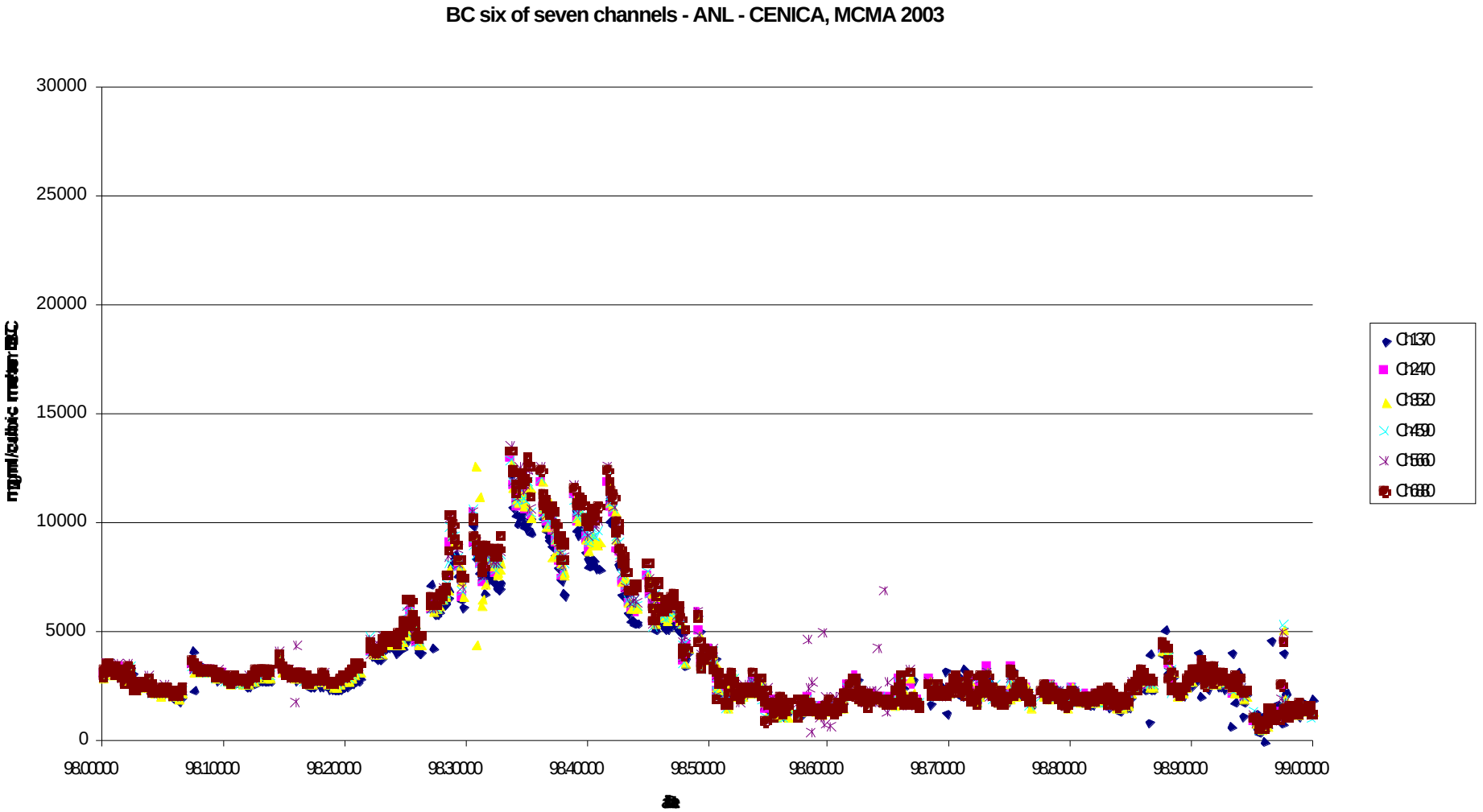
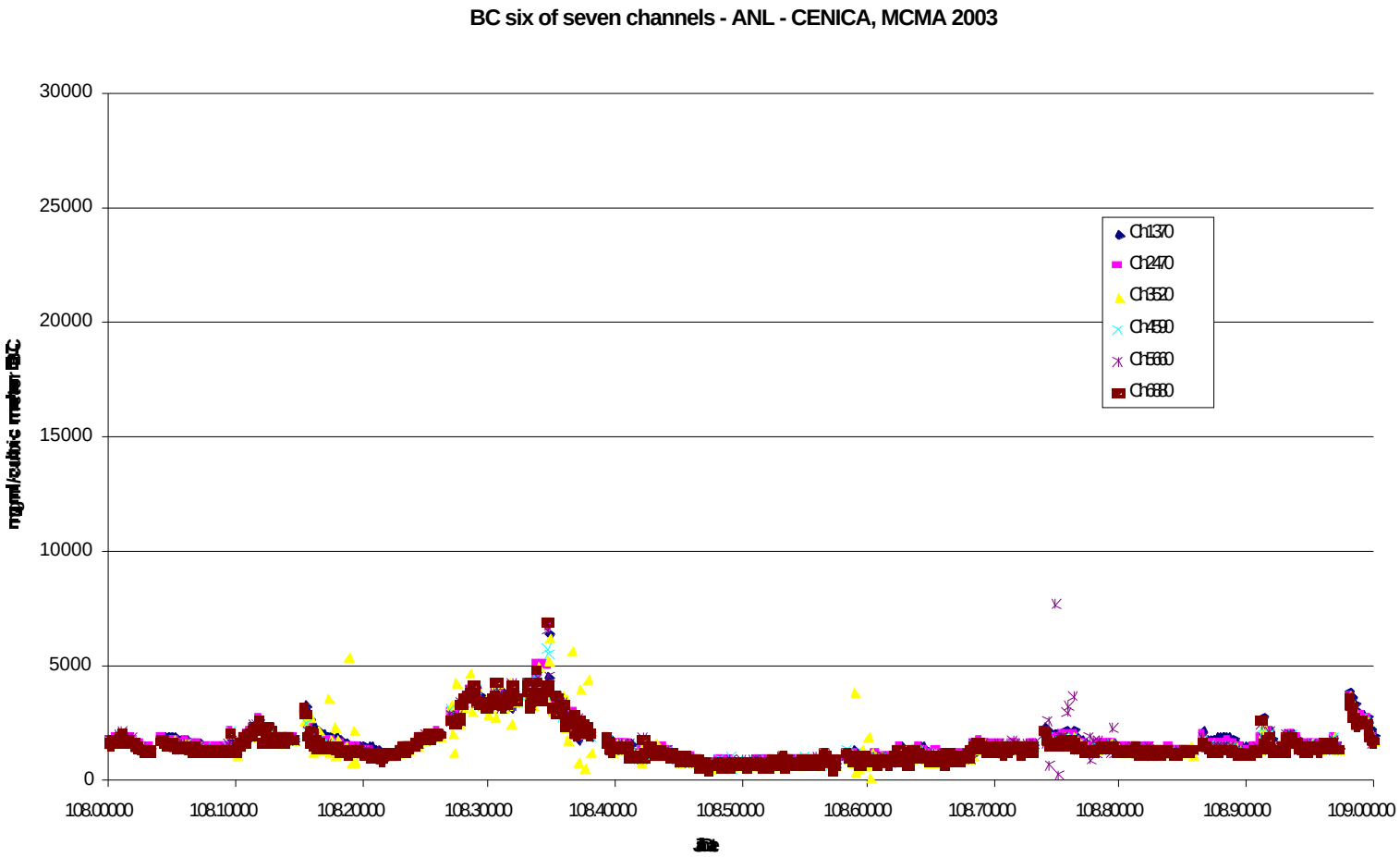

BC six of seven channels - ANL - CENICA, MCMA 2003
30000
25000
20000
15000
10000
5000
0
94.00000
94.10000
94.20000
94.30000
94.40000
94.50000
94.60000
94.70000
94.80000
94.90000
95.00000
Ch1370
Ch2470
Ch3520
Ch4590
Ch6660
Ch6880

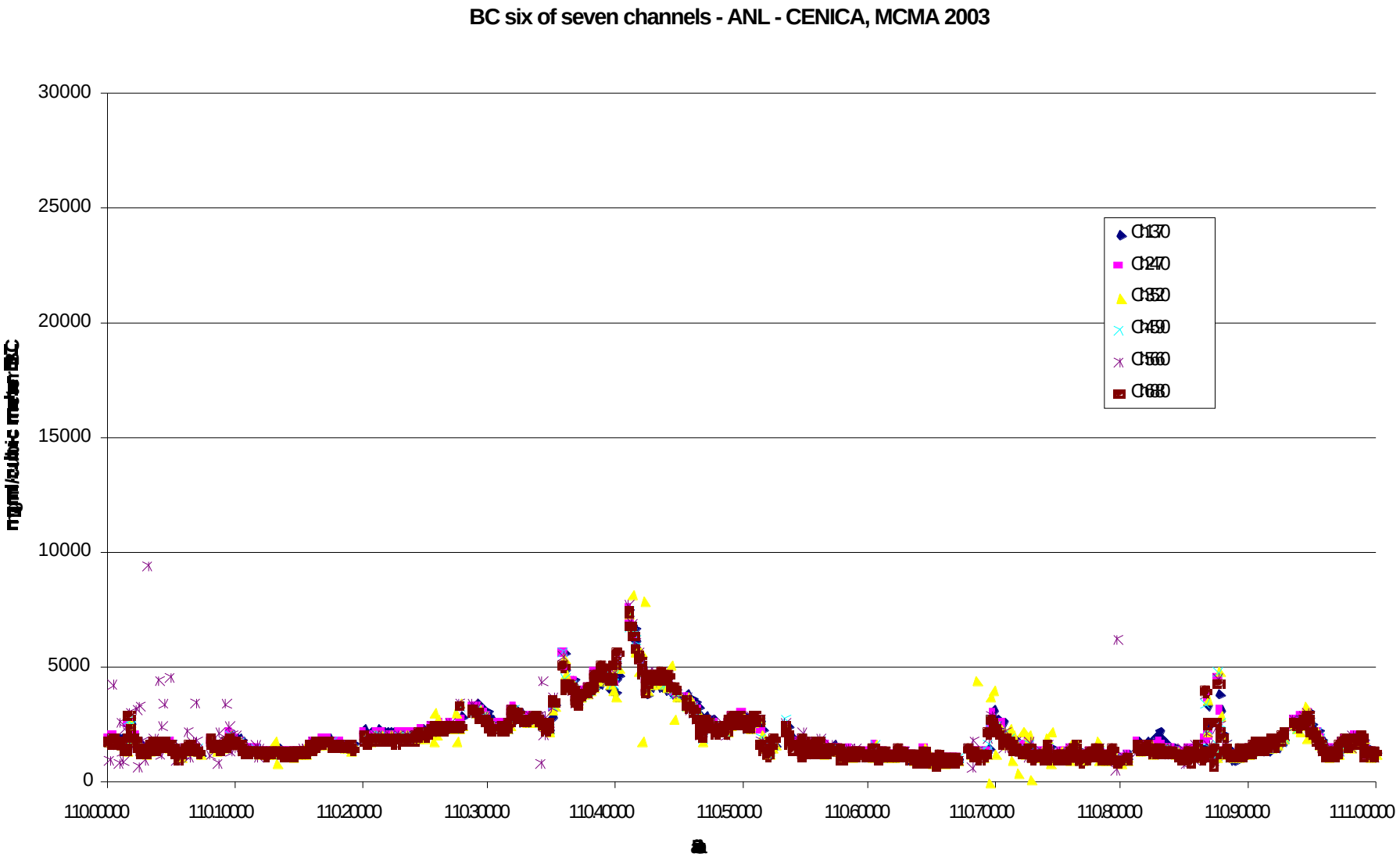
APRIL 8, 2003


BC six of seven channels - ANL - CENICA, MCMA 2003
30000
25000
20000
15000
10000
5000
0
98.00000
98.10000
98.20000
98.30000
98.40000
98.50000
98.60000
98.70000
98.80000
98.90000
99.00000
Ch1370
Ch2470
Ch3520
Ch4590
Ch5660
Ch6880

APRIL 18, 2003



APRIL 20, 2003 - EASTER



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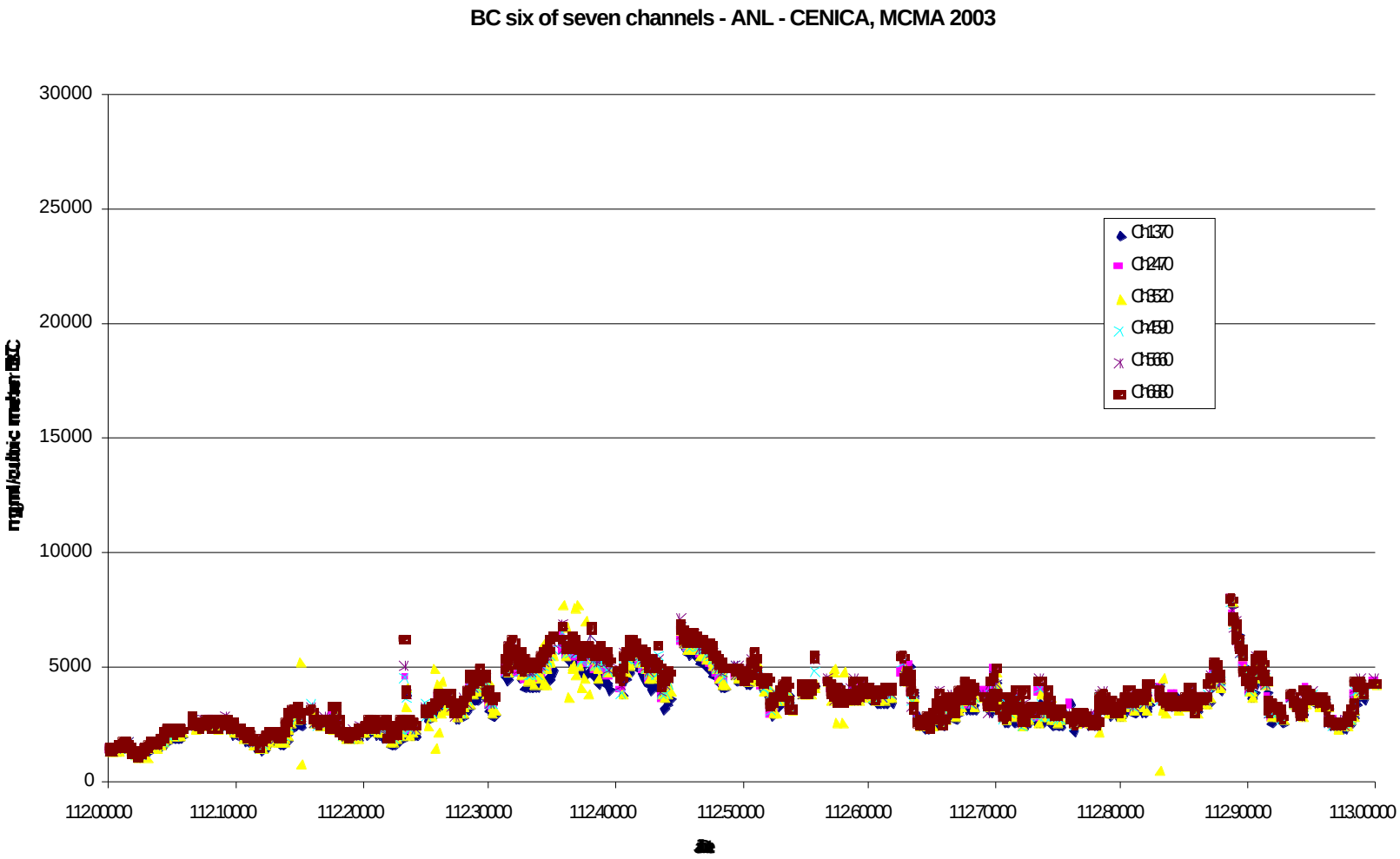

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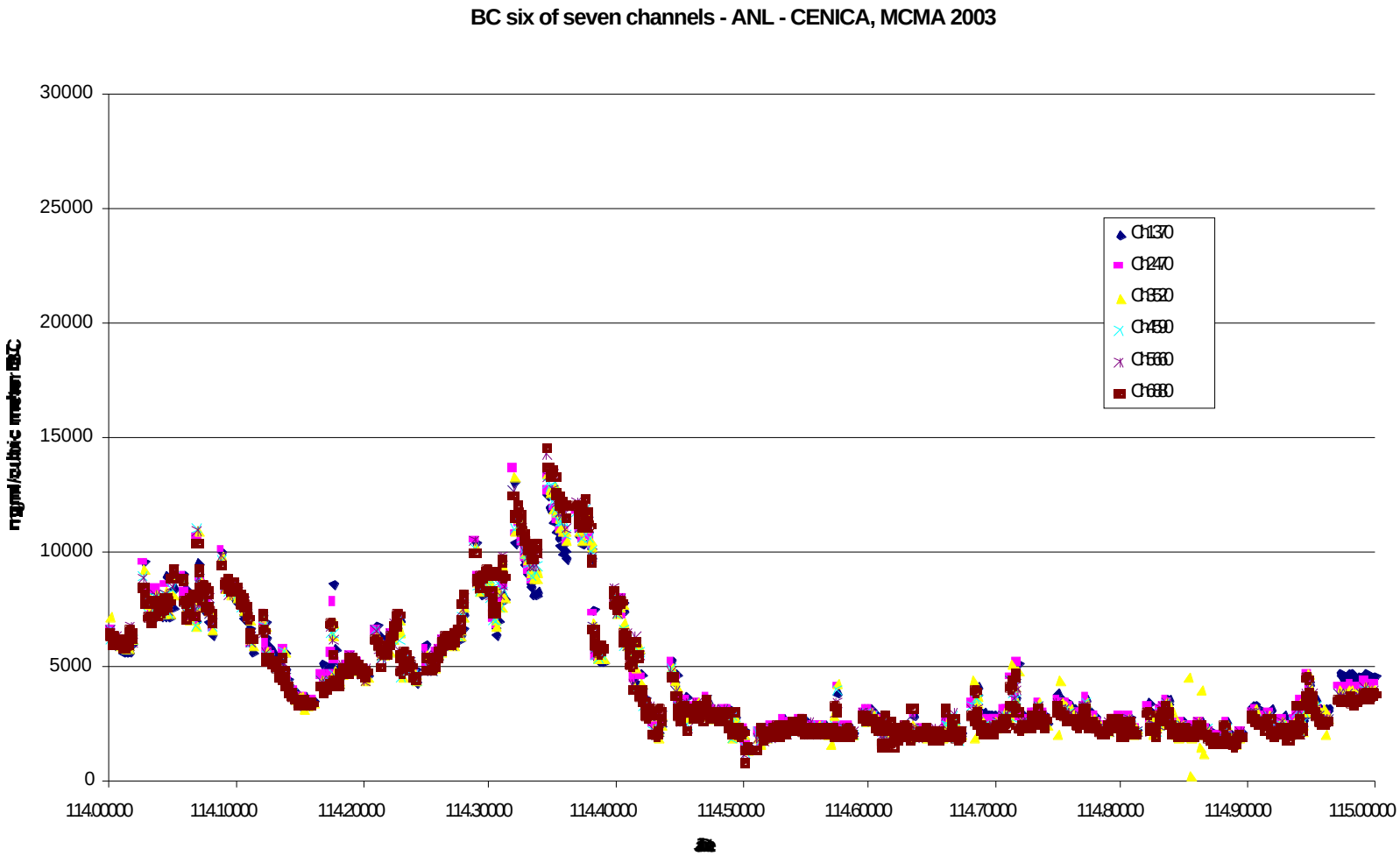

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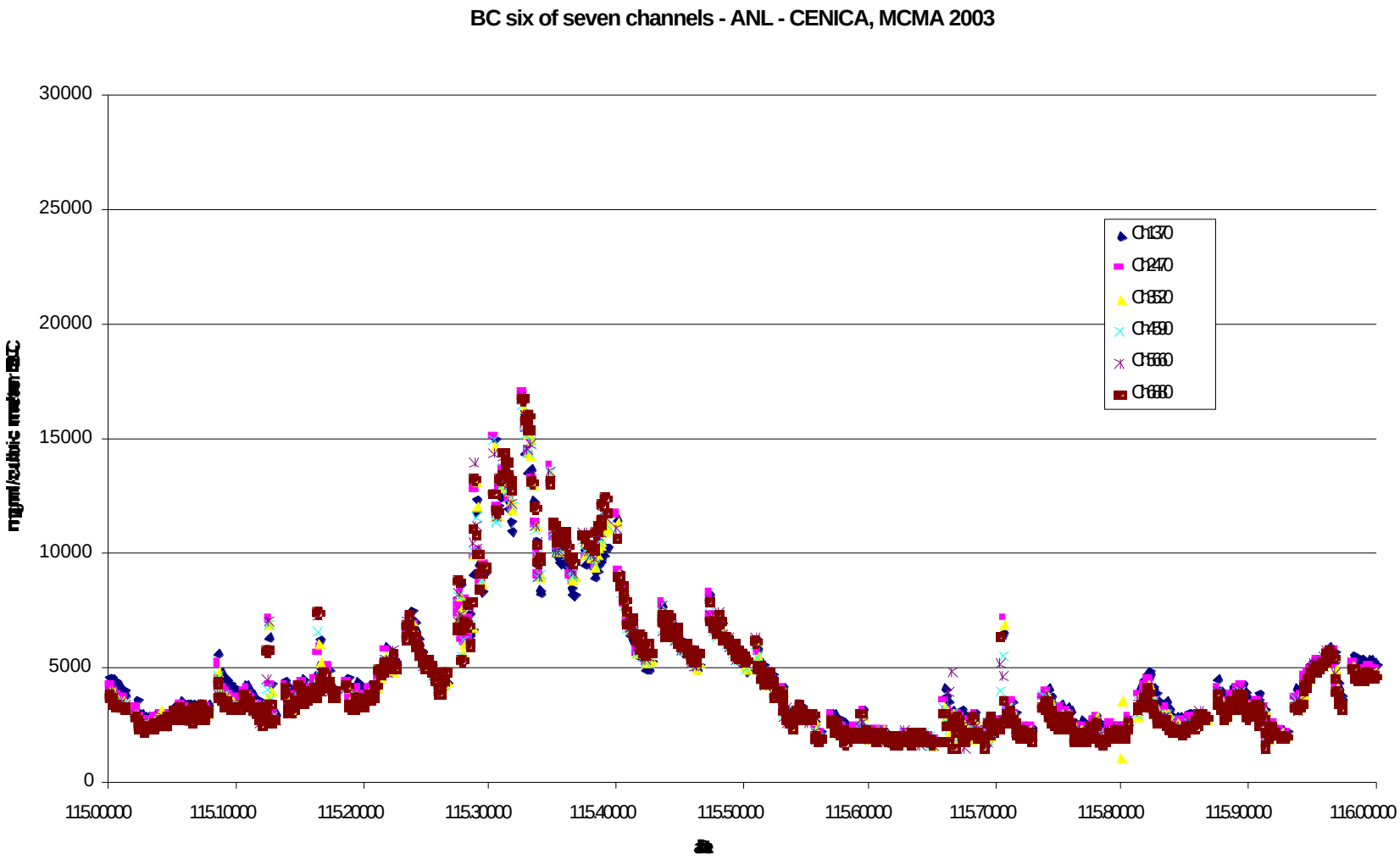
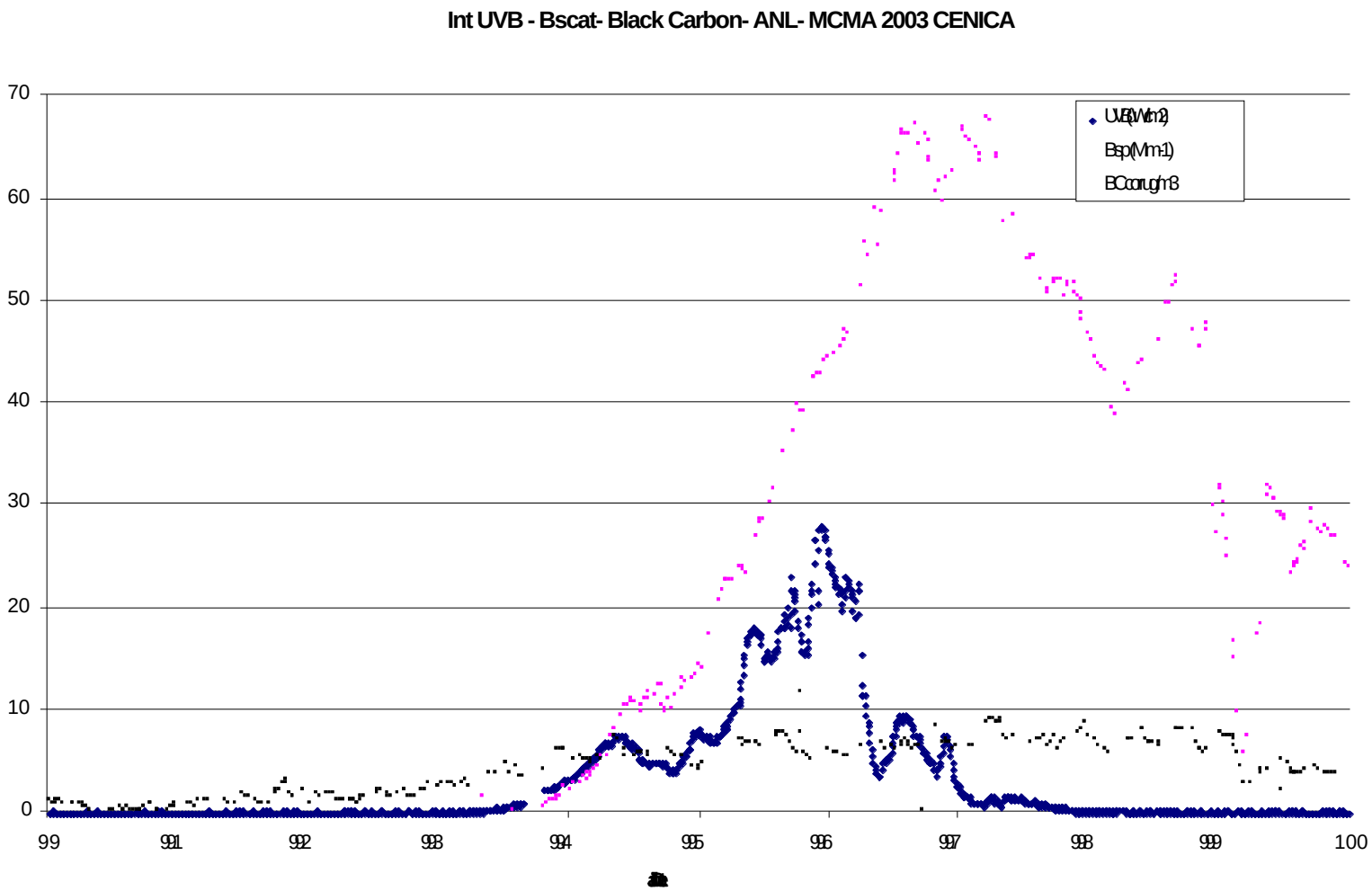
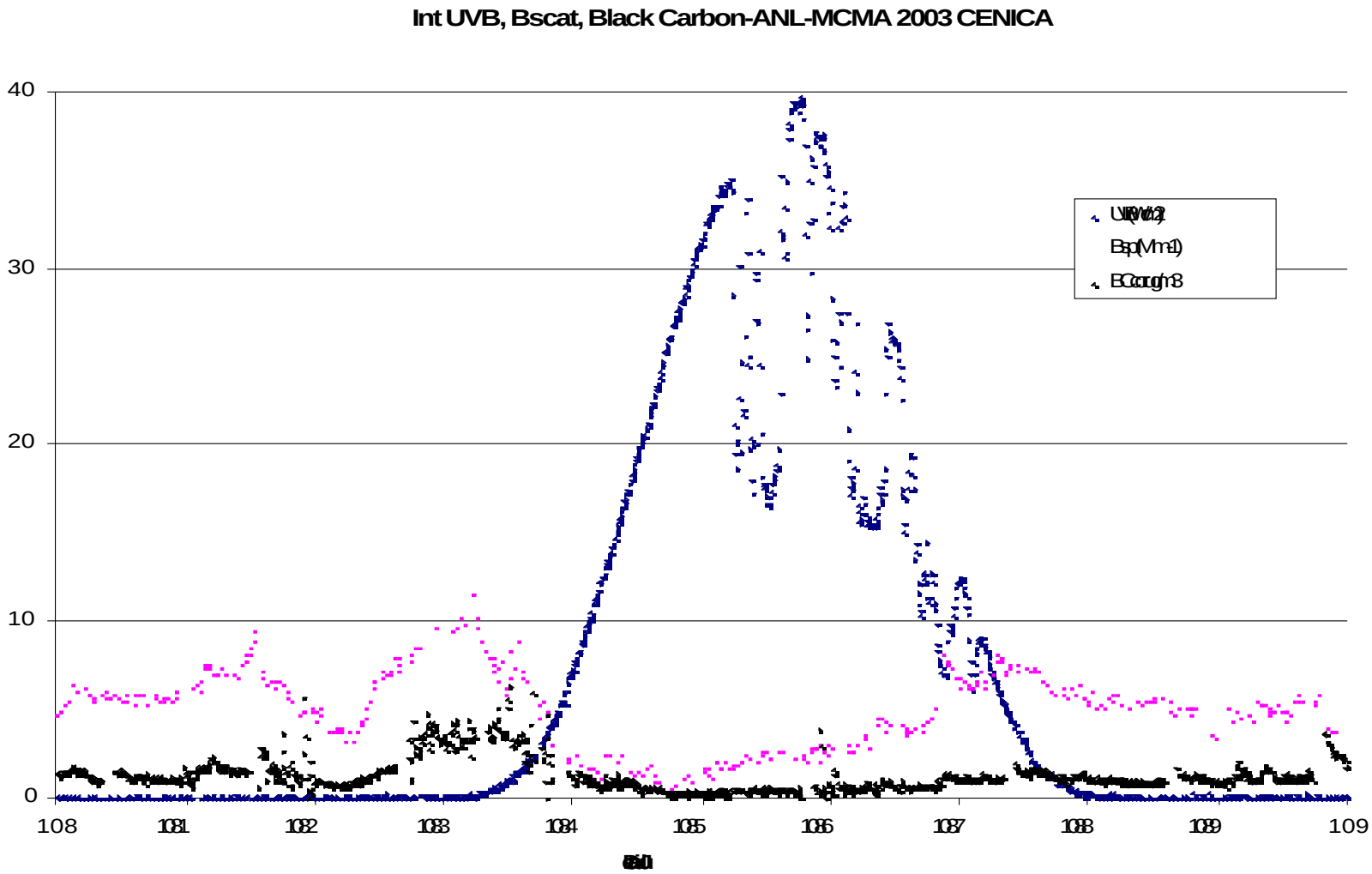


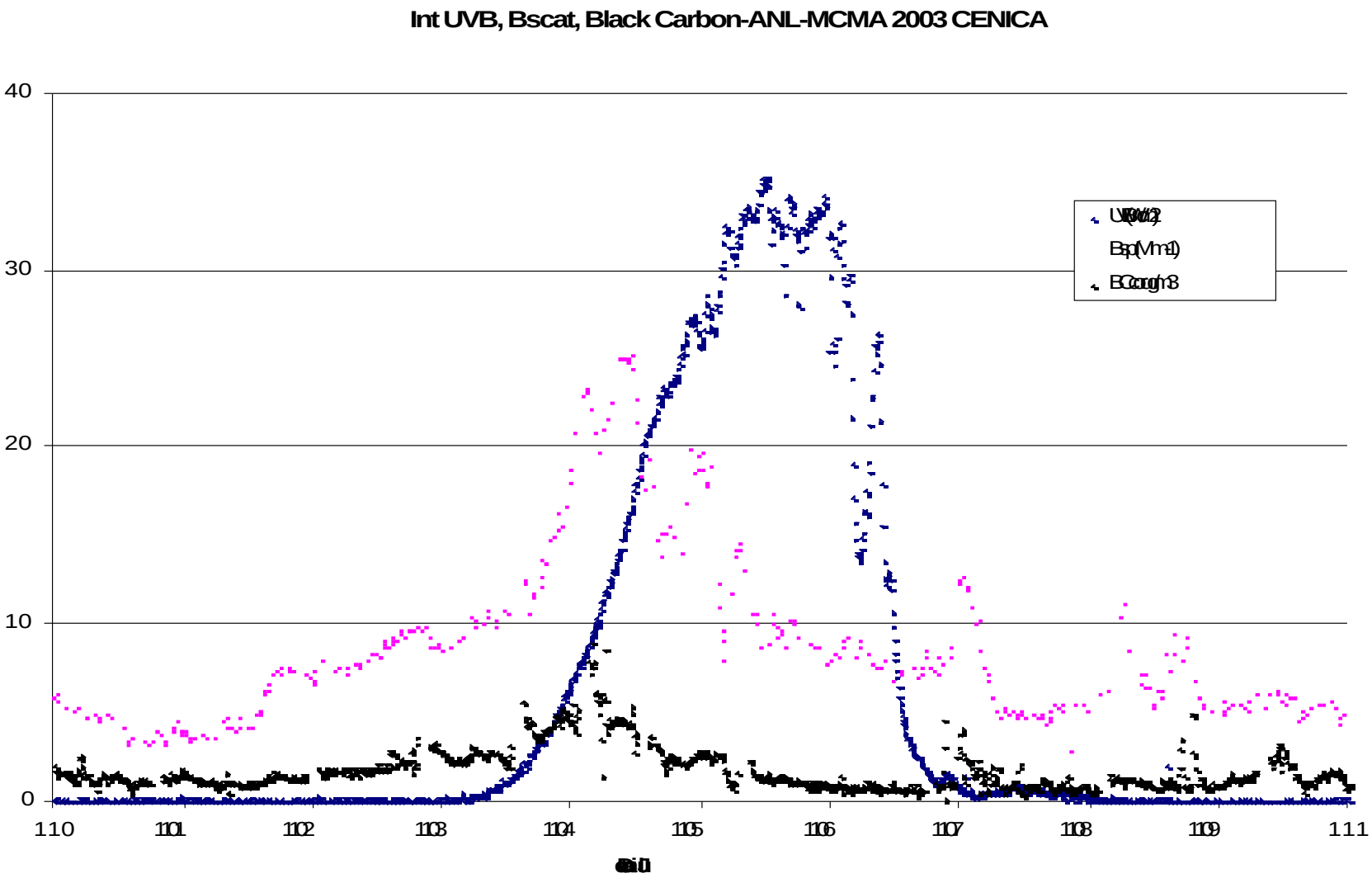
April 9, 2003


Int UVB - Bscat- Black Carbon- ANL- MCMA 2003 CENICA
70
60
50
40
30
20
10
0
99
991
992
993
994
995
996
997
998
999
100

April 18, 2003



APRIL 20, 2003 – EASTER SUNDAY



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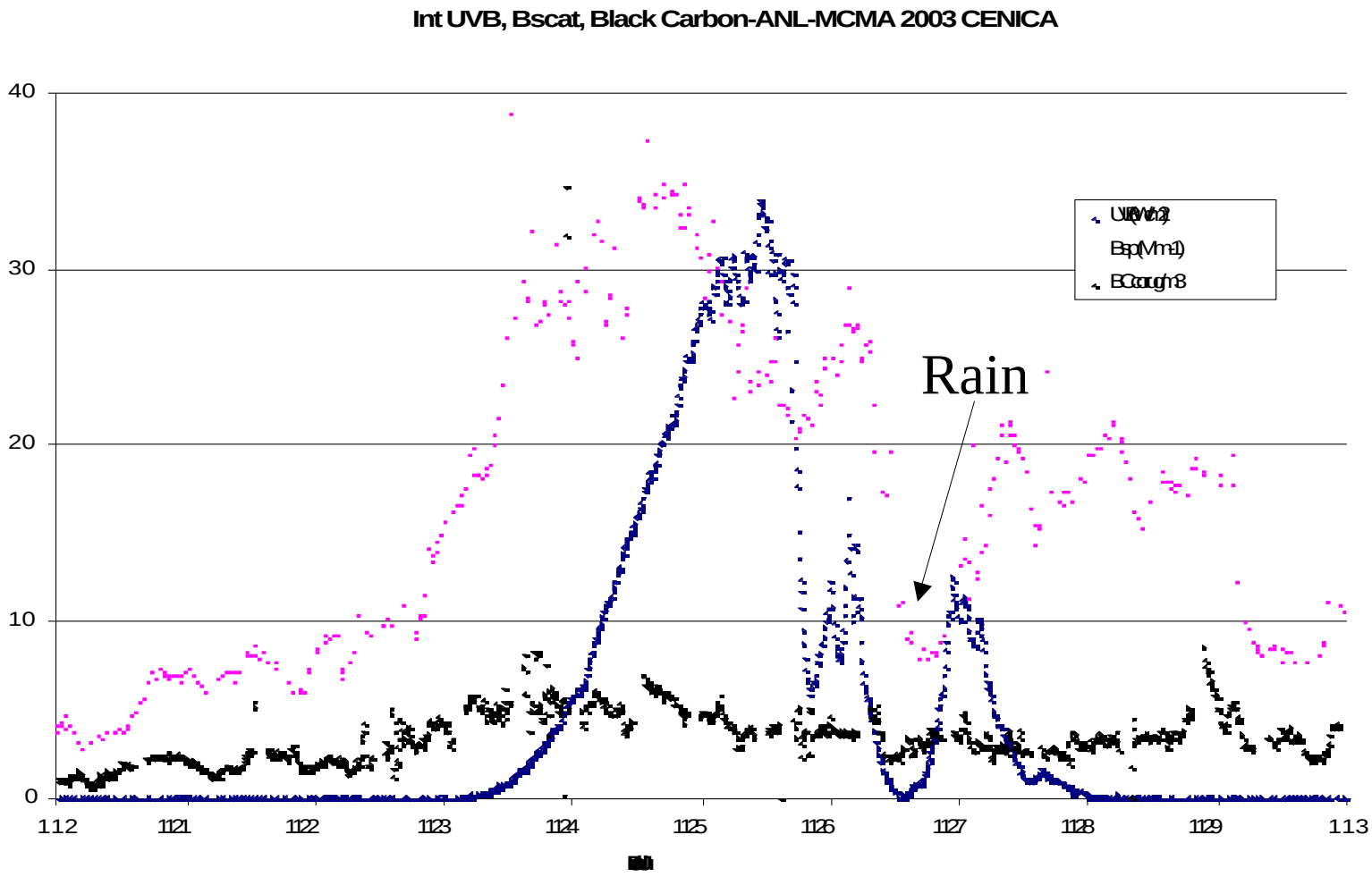

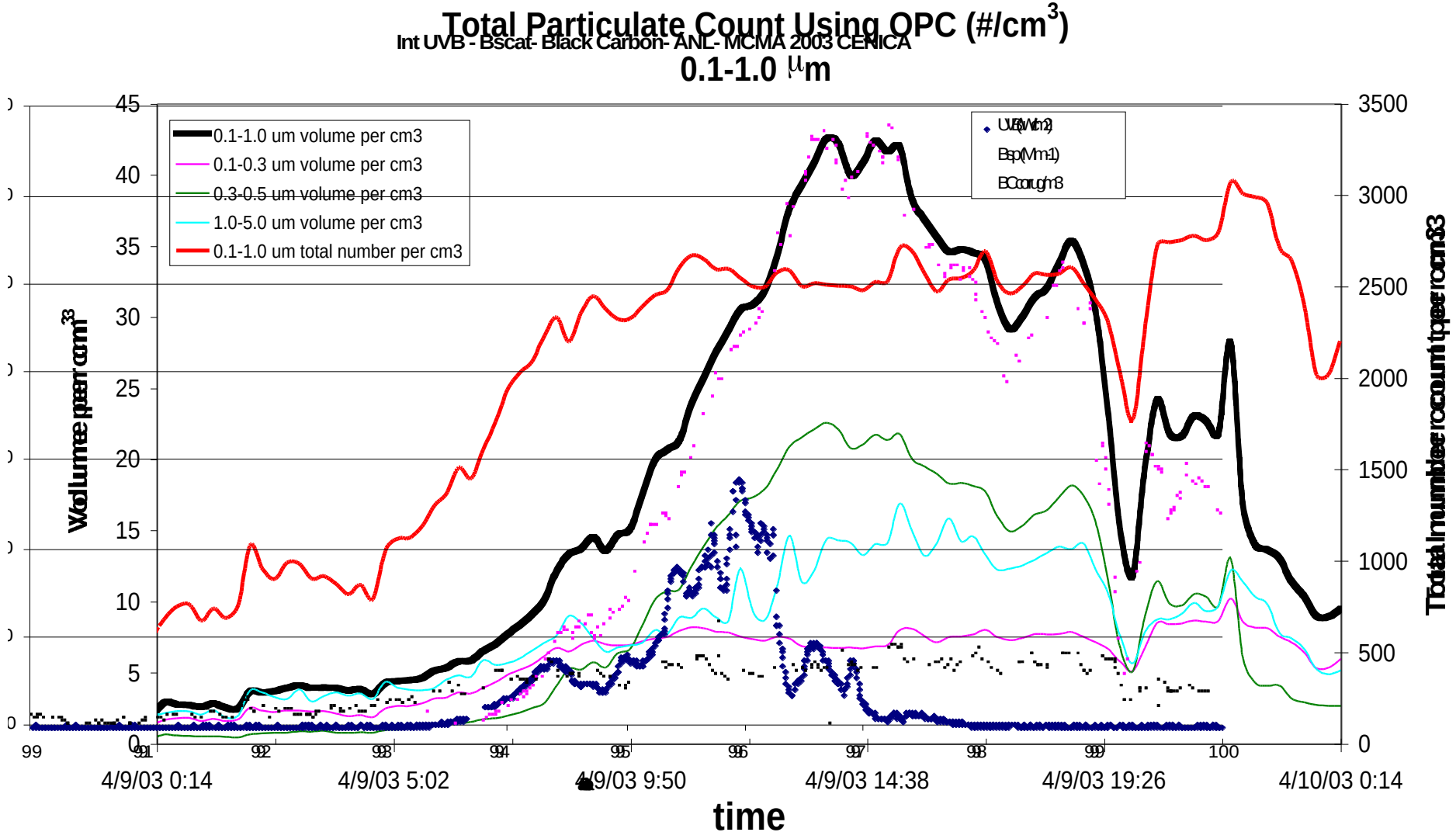
Total Particulate Count Using OPC (#/cm3)
Int UVB - Bscat- Black Carbon- ANL- MCMA 2003 CENICA
0.1-1.0 μm
0.1-1.0 um volume per cm3
0.1-0.3 um volume per cm3
0.3-0.5 um volume per cm3
1.0-5.0 um volume per cm3
0.1-1.0 um total number per cm3
Volume per cm3
Total number per cm3
4/9/03 0:14
4/9/03 5:02
4/9/03 9:50
4/9/03 14:38
4/9/03 19:26
4/10/03 0:14
time